Pupation of *Hemerobius* in Douglas-fir Cones

(Neuroptera: Hemerobiidae)

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Hemerobiids are predators that attack aphidoids and coccidoids; some species are known to have voracious appetites (Killington, 1936), but North American species are usually considered uncommon (Smith, 1923) and thus presumably have a negligible effect on their host populations. Recently, Neuenshwander *et al.* (1975) has shown that one species, *Hemerobius pacificus* Banks, is sufficiently abundant to be a significant predator of aphids. In western North American *H. pacificus* is the most frequently encountered hemerobiid as it occurs on herbacious vegetation as well as on deciduous shrubs and trees. It now appears that other species of *Hemerobius* may also be abundant, but seldom seen because they remain in the crowns of conifers. With the discovery of a principle pupation site of hemerobiids in Douglas-fir *(Pseudotsuga menziesii)* it becomes possible to attempt sampling studies as well as obtain large numbers of specimens for other biological studies.

Records of pupation sites of North American hemerobiids consist of a few casual observations (Smith, 1923) that suggest that hemerobiids pupate in any small enclosed space such as a bark fissure or a curled leaf. Extensive records of pupation sites of European hemerobiids (Withycombe, 1922; Killington, 1936, 1937) indicate that arborial hemerobiids travel down the trunk of the tree seeking pupation sites and, in the absence of suitable bark fissures, pupate in moss and leaf litter at the base of the tree. Hemerobiids inhabiting Douglas-fir find in the Douglas-fir cone an idael pupation site adjacent to the larval feeding area.

Materials and Methods

During the winter of 1976-7 Douglas-fir cones were collected in Seattle city parks (Ravenna, Seward) and on the University of Washington campus. Most of the cones were gathered beneath mature trees. At several sites cones from previous years were removed from beneath the trees so that freshly fallen cones containing recently pupated hemerobiids could be easily gathered after wind-storms. Since hemerobiid cocoons remain concealed even in dry, fully open cones, it was necessary to dissect the cones scale by scale, using Crescent (942-5) wire cutters. The cocoons were removed from the cones and placed on a cone scale on a pad of paper toweling in 100 X 15 mm. Petri dishes. The Petri dishes were kept at room temperature and the paper toweling was moistened with a few drops of water every day.

Results and Discussion

During this investigation 700 recently fallen cones were gathered at random beneath mature Douglas-fir trees. When dissected in the laboratory these cones produced a total of 1,038 hemerobiid cocoons, including 615 occupied cocoons, 372 empty cocoons, 51 parasitized cocoons; 11 active hemerobiid larvae were found. Many pupae and mature larvae were damaged when removed from the cones; 506 specimens were reared to maturity. The species obtained are discussed in the following annotated list.

Hemerobius stigmaterus Fitch.

Reared 223 females, 212 males, time required for emergence in laboratory 1-24 days; 92% emerged 5.20 days after brought into laboratory. Trees that are heavily infested with aphidoids, particularly *Adelges cooleyi* (Gillette) may have an average of more than one *H. stigmaterus* in each cone, indicating that *H. stigmaterus* may be an important predator.

Hemerobius pacificus Banks.

Reared 8 females, 7 males, time required for emergence in laboratory 5-22 days, 90% emerged 6-20 days after brought into laboratory. This species has a much broader habitat range than most hemerobiids; it is regularly found on conifers, broadleaf trees, and herbacious vegetation.

Hemerobius kokaneeanus Currie.

Reared 29 females, 24 males, time required for emergence in laboratory 2-22 days; 90% emerged 8-20 days after brought into laboratory. This relatively large series of a supposedly scarce species shows even more variation in wing markings than described by Carpenter (1940). Wing markings range from a small spot or row of spots on Cu_1 to light spots on all veins and to large dark blotches along Cu_1 and the inner and outer gradates. The amount of infuscation of the wing membrane is also highly variable and not correlated with the extensiveness of wing markings. A series of specimens shows a progressive lengthening of the blotches along Cu_1 and the outer gradates, culminating in a pair of specimens having the typical markings of *H. bistrigatus* Currie. Carpenter (1940) has already noted the remarkable similarity between the wing shape and genitalia of *H. kokaneeanus* and those of *H. bistrigatus;* this new evidence suggests that *H. kokaneeanus* may be a synonym of *H. bistrigatus.*

Hemerobius bistrigatus Currie

Reared 1 female, 1 male, time required for emergence in laboratory 20 days. This pair of specimens is discussed above under *H. kokaneeanus.*

Kimminsia coloradensis (Banks).

Reared 1 female, time required for emergence 14 days.

Douglas-fir cones make ideal sites for hemerobiid cocoons. Hemerobiids inhabiting Douglas-fir avoid the often lengthy and hazardous search for suitable bark crevices, many of which are already occupied by predators, particularly spiders. More predators undoubtedly await hemerobiids that are forced to pupate in leaf litter or moss. Douglas-fir cones, though occasionally inhabited by spiders, are poor habitats for large or mobil predators because the cones

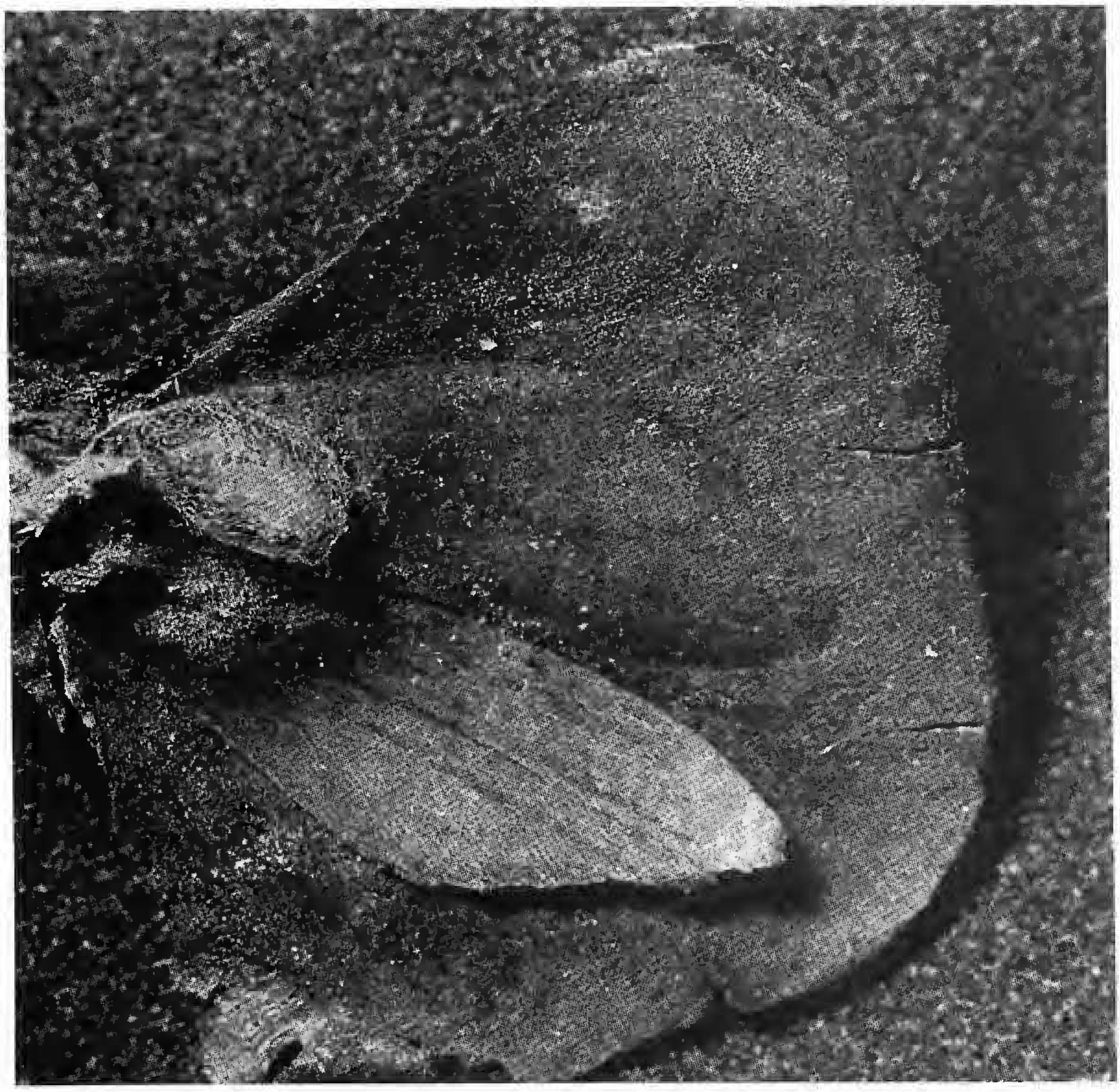

Fig. 1. Pupa of *Hemerobius* occupying depression left by fallen Douglas-fir seed. X 5.

close tightly during wet weather, leaving only a minute space at the base of each scale. The Douglas-fir seeds occupy a pair of depressions at the base of each cone scale; after the seeds fall each depression forms an oval hollow the size and shape of a hemerobiid cocoon. The hemerobiids show great constancy in choosing these hollows for pupation sites, even though the open cone during a period of dry weather offers a variety of apparently suitable crevices. Only a few larvae were found to have spun cocoons outside of the seed depressions; these larvae had been crushed by the closing of the cone during wet weather.

Although there are obvious mutually beneficial relationships between conifers and hemerobiids, it does not seem likely that the structure or mechanics of the Douglas-fir cone has been modified to provide shelter for hemerobiids. It is possible that hemerobiids in the Douglas-fir forests of western North America show behavioral adaptations that facilitate exploitation of Douglas-fir cones as pupation sites.

The abundance of Douglas-fir hemerobiids, and their dependable occurance in special pupation sites are factors that allow exploitation by a number of parasitoids. During the present study 8 species of hymenopterous parasitoids were reared from *Hemerobius* cocoons. There is one previous record of a parasitoid of Nearactic *Hemerobius* (Muesebeck *et al.*, 1951); there are also records of parasitoids of *Micromus* (Selhime and Kanavel, 1968) and *Symphorobius* (Muesebeck *et al.* 1951). Four of the parasitoids are ichneumonids of the genus *Charitopes:* these species oviposit on mature larvae within their cocoons and are obvious beneficiaries of the constancy with which hemerobiids choose their pupation sites within the Douglas-fir cone. Three other parasitoids are figitids, including one species of *Anacharis* and two species of *Aegilips;* these species presumably oviposit in larvae before the cocoon is spun. A few specimens of an unidentified ceraphronid were reared from *Hemerobius* cocoons. Only one parasitiod is produced per host, with the exception of the ceraphronid, a pair of which may emerge from a single host cocoon.

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